CONCRETE FOUNDATIONS

Published by

Portland Cement Association

111 West Washington Street

Chicago

"Concrete for Permanence"

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EVERY building should rest upon a good foundation, and for a number of reasons, such a foundation should be in the form of a continuous wall rather than of small piers spaced at intervals, because the wall prevents the entrance of rats and mice, and makes the support given to the structure equally firm at all points.

Many advantages result from using concrete for building foundations. There are no cracks nor crevices in which vermin or filth may lodge, no repointing or similar repairs necessary as common with masonry construction, and concrete foundations may be built by ordinary laborers under the supervision of some one who knows and enforces the principles of good concrete work. Most of the necessary materials may be found on the farm or near where the work is to be done.

Figure 1. Concrete foundation for small building such as might be used for milkhouse. Such a foundation is rat-proof, rot-proof and expense-proof.

Carrying capacity is the quality most desirable in any foundation. As well-made concrete has great compressive strength, which is the ability to carry loads placed directly upon it, it is not surprising that concrete has won its present deserved popularity for foundation construction, almost to the exclusion of all other materials. It is especially strong, durable, moderate in cost, easily mixed and placed, and can be adapted to irregular excavations which, if filled by masonry construction, would require skilled laborers or would make the work difficult or unnecessarily expensive, without in the end providing the stability and durability that would come from using concrete. Whether the building to be supported is large or small, concrete will meet all foundation requirements.

In addition to being strong enough to carry the load of the building that is to be placed upon it, a foundation should be watertight, especially if it is to enclose a basement or cellar; and watertightness may more readily be obtained with concrete than with any kind of masonry.

Watertightness is secured by proportioning materials so that voids, or air spaces, will be filled, and then by so mixing and placing the concrete that greatest possible density will result. Finally, the concrete must be protected after placed to prevent too rapid drying out.

Soil conditions differ in various locations, so that it is not possible to give definite instructions for some details of foundation work which will fit all conditions. However, certain suggestions may be offered that will apply under average conditions.

Frost may penetrate the ground from $2\frac{1}{2}$ to 6 feet or more in some latitudes, so foundations should be started below possible frost penetration. Therefore, even though there is not to be a cellar or basement under the structure, the foundation trench may have to be excavated to a depth of 6 feet, sometimes more.

When firm soil is not found at the depth considered necessary to meet other conditions, excavating should be continued until good firm soil is reached, or a wider footing used to distribute the load over a greater area. Sometimes the weight of a structure to be carried is such that for economy

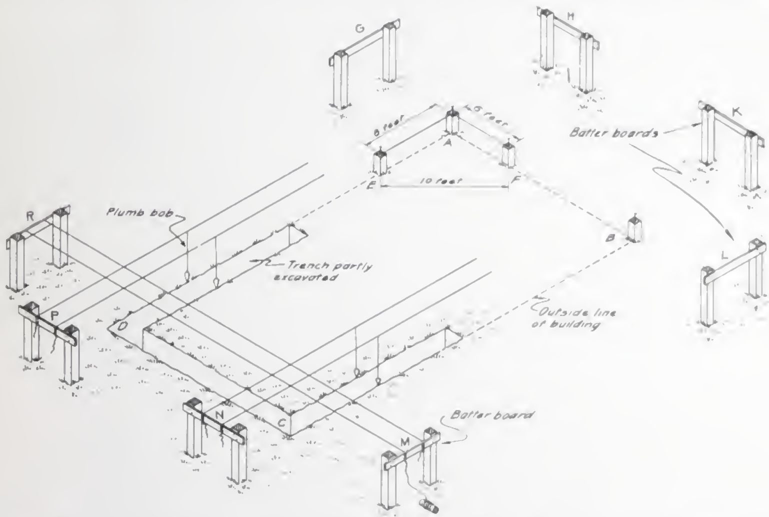


Figure 2. An illustration of the method commonly used to lay out foundation lines and to square building corners.

of concrete in the foundation walls it is advisable to start the foundation with such a footing, which is a layer of concrete varying in width and thickness in accordance with the load to be carried and providing for distributing the load over a greater area of soil.

For barn walls, a footing 2 feet wide and 1 foot thick is generally sufficient. For residences of average size, 18 inches wide and 1 foot thick will probably be sufficient under most conditions, while footings 12 inches wide and 8 inches thick will serve for small farm buildings such as hog and poultry houses.

Wall thickness is governed largely by the type of building. Walls 12 inches thick for basement barns are usually safe. For the average residence and low barn, 10 inches will probably be sufficient. Small

structures such as poultry houses, hog houses, garages and similar buildings usually require walls varying from 6 to 8 inches thick.

Heavy walls below ground that are to serve as a foundation only, that is, which are not intended to enclose a basement or cellar, should be built of a concrete mixed in the proportions 1 : 2½ : 5. (A 1 : 2½ : 5 mixture means 1 sack of Portland cement to 2½ cubic feet of clean, well-graded sand, to 5 cubic feet of well-graded pebbles or broken stone.) Very massive foundations and footings may be of a 1 : 3 : 6 mixture; but if the foundation wall must be of watertight construction, then a 1 : 2½ : 4 mixture is necessary, this being sufficient to secure watertightness against

Figure 3. This view illustrates the actual performance of the work suggested in Figure 2.

ordinary ground water where there is no direct pressure or head of water. If there is such water pressure, as in machinery pits that must be sunk to considerable depth, sometimes below the normal level of ground water, then a 1 : 2 : 3 mixture is necessary to afford the desired resistance to the passage of water.

Where a foundation is to serve as the enclosing wall of a basement or cellar, naturally the foundation must be carried down far enough to give the necessary head room or height to the cellar.

As nearly all buildings are of rectangular form, laying out a foundation is a relatively simple matter. First, the desired location of the building as relates to some nearby structure or as regards general convenience is determined, and the location of one corner marked by a stake, as at

A in Figure 2, with a small nail partly driven in the top of the stake to mark its center. Another stake should be driven at F, so that the center of its top will be exactly 6 feet from the center of stake A. Stake E should be driven so that its center is exactly 8 feet from the center of stake A. Stake E may then be moved to the right or left, as necessary, to make the distance between the nails in stakes E and F exactly 10 feet. This will mean that the corner represented by the stakes E A F is "square," or a right angle. Other corners are located in a similar manner. After this has been done, strings should be stretched from the corner stakes A, B, C and D (in Figure 2, the stakes C and D have been removed on account of the partly excavated trench), and the lines indicated by these

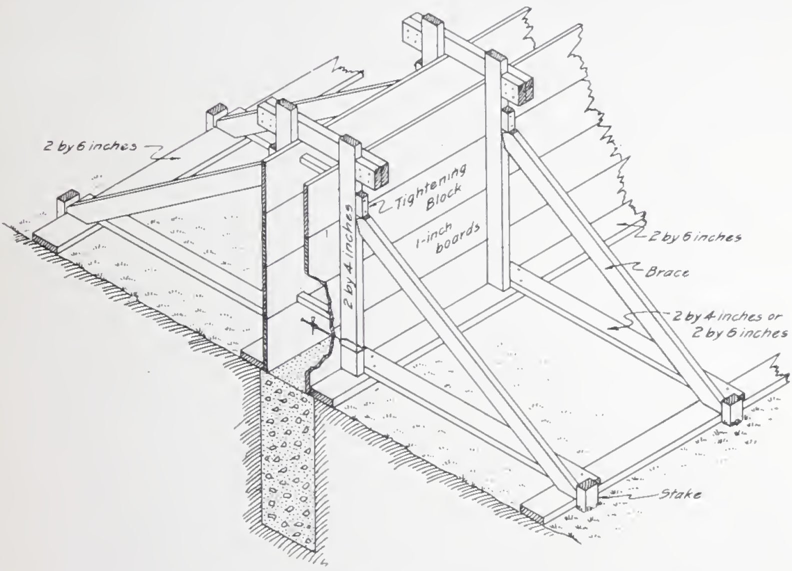


Figure 4. Simple form for foundations for small buildings, such as might have been used in constructing the foundation shown in Figure 1. No forms are necessary below ground when the earth is self-sustaining.

strings carried to outside stakes, or standards, indicated by G, H, K, L, M, N, P and R, two strings being used and placed a distance apart equal to the width of the trench to be excavated. A plumb bob suspended from a string can then be used to transfer the building lines from the strings to the ground as shown in the drawing. When the outside stakes G, H, K, L, etc., have been placed and the strings indicating the layout of the building transferred to them, the corner stakes A, B, C, D and the intermediate stakes E and F are removed, so that the trench may be excavated. Figure 3 illustrates clearly how the corner is tested for squareness as previously described. After having made the layout as shown in Figure 2, it is very easy, while strings are in place, to locate

intermediate supports such as foundation piers, which may be necessary inside of the main excavation to support columns or posts of the proposed building.

When the soil is firm, so that the walls of the trench are self-sustaining, it is sometimes not necessary to use forms for that portion of a foundation wall below ground. All that is necessary is to carefully excavate the trench with true vertical sides, then to lay boards or planks along and across the trench so that workmen, when placing and spading concrete, will not knock down earth from the trench sides into the concrete.

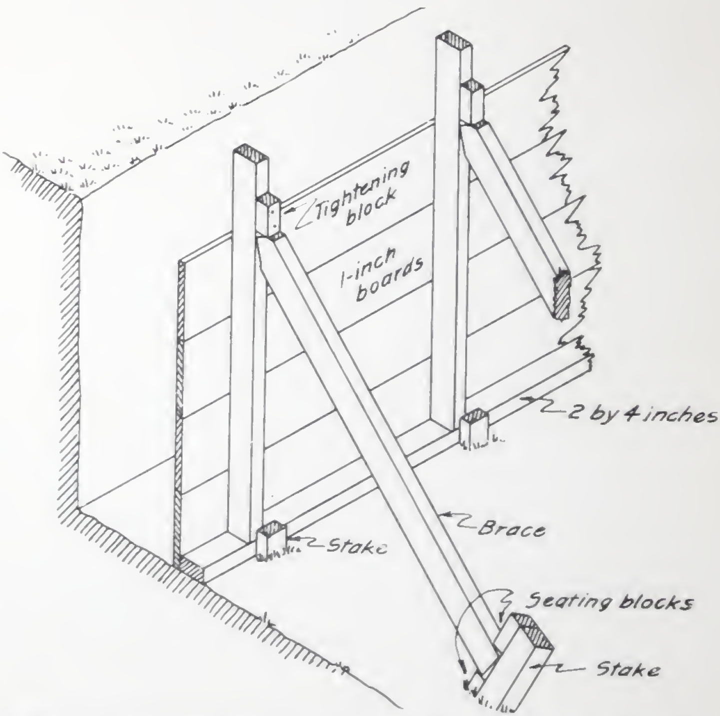


Figure 5. Type of form used for constructing basement wall when the earth is firm enough to make an outside form unnecessary.

Concrete placed in an earth trench without the use of forms is shown in Figure 4. After the trench has been filled to ground level, the concrete is carried higher to form the remainder of the foundation or to build the walls for the structure, by building and setting in place forms such as shown in this illustration. In constructing forms it is always well to avoid using more nails than necessary so that when the forms have to be taken down, they can be removed with the least amount of hammering, thus preventing possible injury to concrete which has not thoroughly hardened,

and also to avoid unnecessary injury to form lumber, which can be put to other use if desired or be made to serve a number of times for concrete forms.

Forms should be set so that the sides are truly vertical. This will make opposite form faces parallel. They may be held the correct distance apart by clamping them against spacers, with wire ties or wood clamps, as shown at the cut-away portion of the form sheathing in Figure 4 and at the tops of form studs in the same illustration.

Sometimes it is desired to give a foundation greater resistance to side pressure or perhaps to provide a firmer base, as in retaining walls. Then the forms are set so that one face of the wall will have a batter or slope. This can be accomplished by using a short spacer between the forms at the top and a longer one between forms at the bottom. Care should be taken not to build walls too light, that is, lacking the strength necessary. Retaining walls often require careful design. The Portland Cement Association will be glad to advise with you on any such problems.

In Figure 5 there is shown the form construction usually employed when a wall is to enclose a basement or cellar and the earth is sufficiently firm and self-sustaining to make an outside form unnecessary.

Form studs for most small work should be 2 by 4's spaced not farther than 2 feet apart, in which case 1-inch boards will do for form sheathing. Additional details of foundation form construction are shown in Figure 5, where a footing is provided at the bottom of the trench, so that the load of the foundation wall may be distributed over a larger area of soil. This footing can be built without planning the forms especially for the purpose, by simply blocking the wall forms up from the bottom of the footing trench as shown, and allowing the concrete to spread; but this does not mean that a concrete so wet as to "flow" is used. Be careful not to use more water than will produce a "quaky" mixture.

Figure 6 shows a double form indicating how forms should be constructed in case both inner and outer ones are necessary because of the soil not being self-sustaining. Braces should be strong enough to hold the forms rigidly against bulging or spreading. Usually 2 by 4's will be found suited to most needs.

At the top of the form in Figure 6 there is shown an anchor bolt supported by a block laid across the forms. This illustrates the method by which bolts are embedded in foundations for the purpose of anchoring the sills of a frame structure. The right-hand portion of Figure 6 illustrates a section of the form filled with concrete and the anchor bolt set in place.

When placing concrete for foundations, a properly proportioned, "quaky" mixture, such as would be used to secure watertight construction, should be thoroughly spaded next to form faces and between them so as to secure the greatest possible density and compactness. If a mixture containing less water than would produce a quaky concrete is being placed, the concrete is tamped in the forms or foundation trench by using a wood block to which a handle is attached.

No material is better suited to foundations for gas engines, cream separators and similar machines than concrete. The depth to which

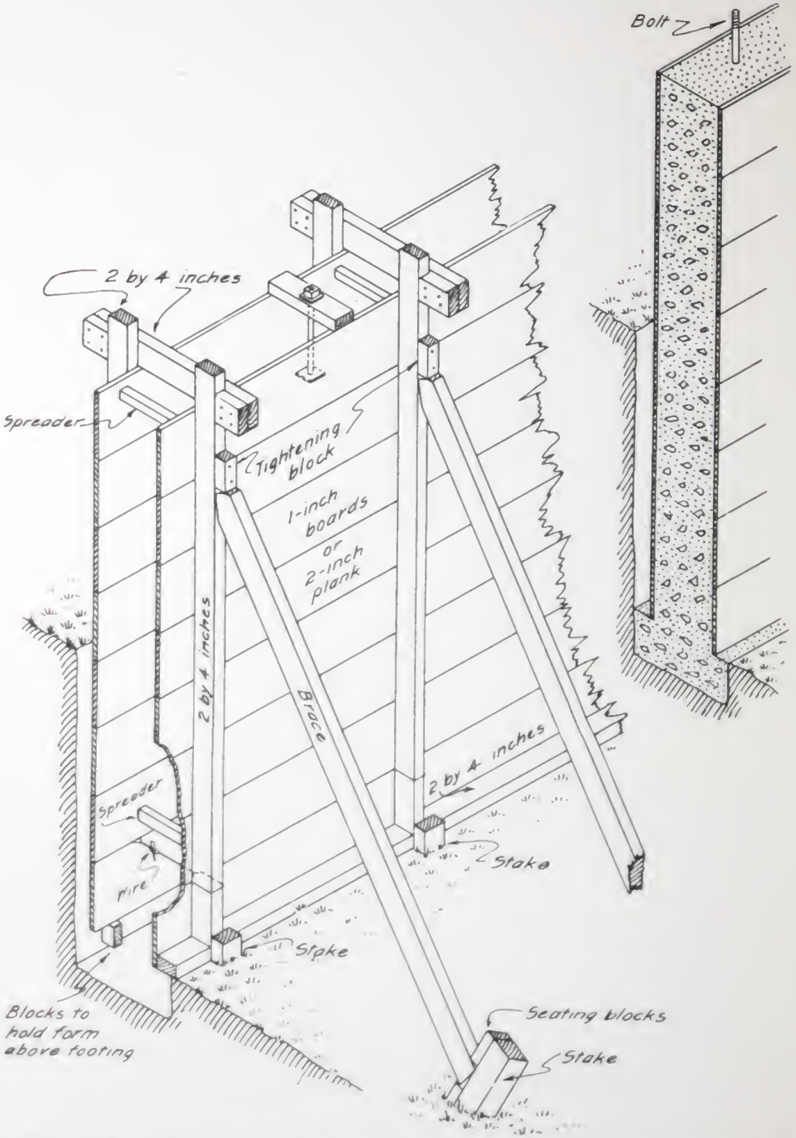


Figure 6. Type of form that may be used when necessary to provide a small footing for the foundation and when both inside and outside forms are necessary. This illustrates also the method of fixing anchor bolts in the foundation for the purpose of securing in place wood sills of a frame superstructure.

such foundations should extend depends upon the size of the machine and the bearing power of the soil. Figures 7 and 8 illustrate the method of building forms for a concrete foundation, such as would be used to support a gas engine. A section of concrete floor is shown simply to illustrate that the engine foundation should be separated from the floor by a perfect joint, that is, floor and foundation should be laid independently of each other.

As in the case of other foundation work, if the soil is sufficiently firm to stand up when the excavation is made, no forms will be needed for that portion of an engine foundation below ground. It is necessary to arrange

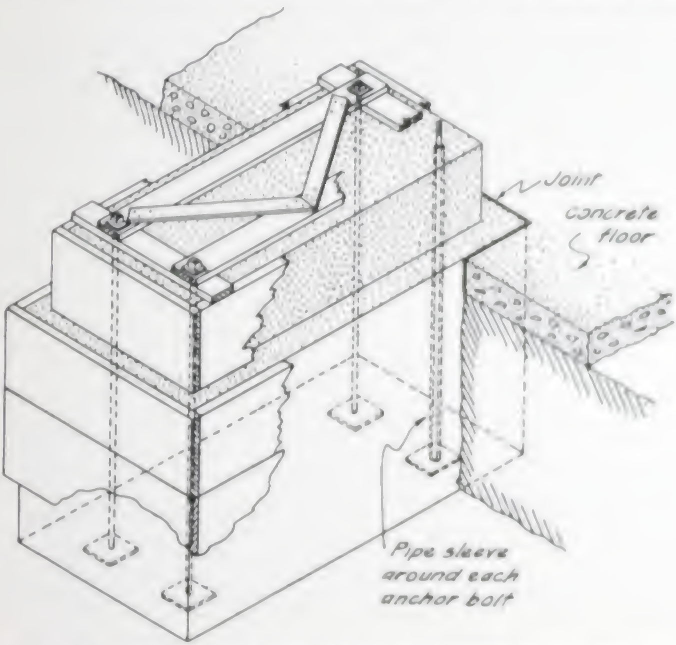


Figure 7. Method of building forms for a foundation such as would be used for a small gasoline engine or cream separator. Notice that the foundation is constructed independently of the concrete floor when such is used.

first for setting the anchor bolts to which the engine or machine is to be attached to the foundation so that they will be in the same position on the top of the finished foundation, as are the corresponding bolt holes in the bottom of the engine or machine.

A form for the upper portion of a foundation like this may be made either of 1 or 2-inch lumber. A template should be constructed of straight-grained 1-inch lumber fastened together by screws, with holes bored in it slightly larger than the bolts which are to pass through them, and located so as to conform exactly with the location of the holes in the base of the

engine or machine to be set. Before placing any concrete the bolts are suspended from the template, head downward, with a washer passed over them to provide additional anchorage in the concrete. Sometimes pipe sleeves are passed over the bolts also, this being for the purpose of allowing a little movement of the bolt later if necessary to make them match up in position with the holes in the engine or machine base. After the threaded end of the bolts has been passed through the template, nuts are attached as shown, to hold the bolts suspended from the template. The threaded end should project above the template a distance sufficient to make certain that bolts will extend well through the engine base casting so as to expose enough of the threaded portion to receive the nuts that are

Figure 8. Forms like those illustrated in Figure 7, in actual use.

to hold the engine in place. Bolt ends which project above the template should be covered while placing concrete, to prevent filling the threads.

In placing the first concrete, care should be taken not to push the bolts to one side so as to prevent them from hanging as nearly vertical as possible. After the form has been filled and the concrete has partly hardened, which will require 45 minutes or more under average conditions, the template may be removed and the foundation top finished to a true level surface; this applies when the bolts have been set in position without using a pipe sleeve. Or, the template may be blocked up slightly so that the finishing can be done underneath it without disturbing the relative positions of the bolts.

When a pipe sleeve is used to permit freedom of movement of the bolts for possible final adjustment, these sleeves are finally filled with a thin grout consisting of 1 part cement to 1 part sand, after the bolts have been fixed in position to correspond exactly to the location of holes in the engine or machine base. Sometimes melted lead is poured into the sleeves as a bolt setting; but this is somewhat expensive where the pipe is a foot or more in length.

Foundation piers or footings are constructed in practically the same manner as described for engine foundations. Piers may be made to carry a heavy load by spreading the footing so that a relatively large area of soil receives the weight. When additional layers of concrete are placed on the first layer of the footing, forms are so constructed that the layers form a series of offsets or steps up to the ground line or desired level.

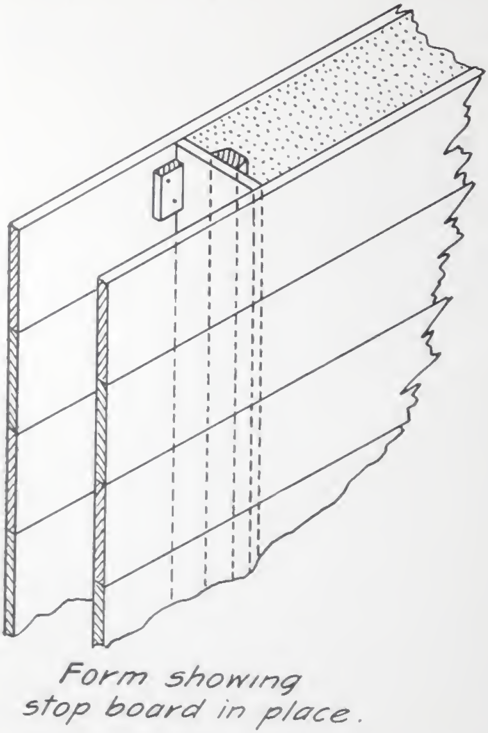
Figure 9. A firm, permanent concrete foundation pier that serves as a shaft support.

All concrete work should be carried on as uninterruptedly as possible, and the concrete be placed in uniform layers so there will not be a slope to the work in the forms. Yet it is sometimes necessary to stop work before a certain portion of a wall or section can be finished. If it is desired to complete the concrete of a certain section up to the top of forms, the way to provide for this is to arrange for a vertical joint in the wall, which may be done by placing a stop in the forms as shown in Figure 10. Usually such joints are not objectionable in a wall that is not to enclose a basement or cellar, and in such a case no special precautions need be taken to make the joint watertight. If, however, such a joint must be watertight, then when concreting of the next section is resumed the end face of the section previously placed should be painted with a thick hot tar just in advance of placing the several layers of concrete so that the joint will be effectively sealed against leakage. In most cases it is best to place concrete in layers from 6 to 8 inches thick, continuously around the space between forms.

When necessary to stop work for the day the surface of the concrete in the forms should be slightly roughened by scratching with a stick, so a good bond can be secured with concrete to be placed later. Before placing additional concrete, however, the roughened surface of the old concrete should be thoroughly washed so as to remove any dirt or rubbish and the surface painted with a paint of cement and water mixed to the consistency of thick cream and applied immediately in advance of placing fresh concrete. If properly done, this will prevent seepage through what would otherwise be a construction seam. The ideal way to build with concrete is to arrange to carry on the work uninterruptedly if possible. But as this is sometimes impracticable for the home worker, the foregoing precautions carefully observed will make the work effective.

As it is desirable that the floor of any building be somewhat higher than the surrounding ground, it is customary to carry the foundation

wall a short distance above ground, which is readily done by simple forms such as shown in Figures 4 and 11. These can either be built in sections and then set in position or built in place, depending somewhat upon the nature of the work. If the inner and outer parts of the form are built separately or in sections, they may be leveled carefully and plumbed as units, while if built in position care must be taken to carefully set, plumb and brace the studs and to be careful when nailing on the sheathing not to knock the forms out of plumb.



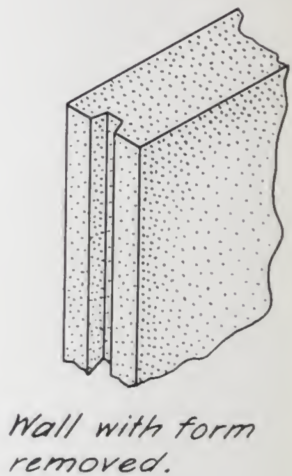


Figure 10. Method of making a vertical joint in a concrete foundation when necessary or desirable to finish concreting in a section up to the entire height of forms.

Concrete blocks are sometimes used for foundation construction and are satisfactory if well made, and laid in rich Portland cement mortar.

If water leaks through foundation walls, it is usually because of porous concrete, that is, a concrete that has not been properly proportioned to fill air spaces in the sand and pebbles nor placed as it should have been. Where conditions are such that long rainy spells may be expected at certain seasons of the year, the prevention of seepage through concrete basement walls is accomplished by using a richer concrete mixture in the construction, or when constructing the wall, to apply to the outside surface

several coats of thick hot tar mopped on with a swab or brush. It is, however, still more important that the cellar floor be of well proportioned, dense concrete, and that where it joins the foundation wall there be a perfectly sealed tar joint; also that if the floor is laid in slabs, that the joints between adjacent slabs be well sealed with hot tar.

Some soils hold water longer than others and it is well where possible to arrange for a drain outlet at some point lower than the bottom of the foundation, to lay a tile drain around and a few inches below the foundation to collect soil water and lead it away from the foundation wall.

Figure 11. A form similar to that shown in Figure 4, which permits carrying the foundation wall the desired distance above ground.

It is seldom necessary to reinforce concrete foundations unless they are to be subjected to excessive side pressure, vibration, or other unusual strains. Sometimes reinforcing is used in long foundation walls extending some distance above ground, to counteract the expansion and contraction due to temperature changes.

Figure 12. The finished work accomplished by using forms similar to those illustrated in Figures 4 and 11. Notice that anchor bolts have been set in the foundation for the purpose of securing sills.

The top of the concrete in foundation wall forms should be properly leveled after the forms have been filled. One method by which a frame superstructure may be fastened to a concrete foundation without using a wooden sill is to embed iron straps in the concrete when placing it, permitting them to project from 8 to 12 inches beyond the top surface of the foundation so that when the

building studs are placed the straps will extend up two sides of the studs, which are then held in place by bolting or nailing the straps to them.

Another and perhaps better method is the one shown in Figures 6 and 12, that is, fixing a bolt in the concrete when the last 6 inches or more is placed in the forms. A sill can easily be attached by boring holes in it to correspond to the position of the bolts, the bolt ends passed through these holes and a nut applied on top of the sills. Another method is to attach a cast iron socket to the top of the concrete foundation by means of bolts embedded in it and to set the studs in these sockets, fastening the studs with nails or bolts. Several types of such stud anchors are now on the market.

Frequently field stones from 4 to 6 inches in diameter may be used in a foundation trench when constructing concrete foundations, and if used, they should be distributed about in the foundation trench after a layer of concrete has been placed, the field stones being laid so that no two are in contact and separated sufficiently to permit thoroughly surrounding them with concrete. Field stones used in the manner described should be clean, and wet before laid in the trench.

The following table, with examples illustrating its use, will be found convenient in estimating quantities of materials required for various volumes of concrete.

QUANTITIES OF PORTLAND CEMENT, SAND AND GRAVEL OR CRUSHED STONE FOR 100 SQUARE FEET OF CONCRETE 10 INCHES THICK, EQUAL TO 3.08 CUBIC YARDS

PROPORTIONS			QUANTITIES		
Sacks of Cement	Cu. Ft. of Sand	Cu. Ft. Gravel or Stone	Sacks of Cement	Cu. Yd. of Sand	Cu. Yd. Gravel or Stone
1	1		60.2	2.23	
1	1½		47.7	2.65	
1	2		39.4	2.92	
1	2½		33.8	3.13	
1	3		29.5	3.29	
1	1	1	41.7	1.54	1.54
1	1½	3	23.4	1.30	2.60
1	2	3	21.5	1.59	2.38
1	2	4	18.5	1.37	2.74
1	2½	4	17.2	1.59	2.54
1	2½	5	15.4	1.43	2.86
1	3	5	14.2	1.58	2.64

NOTE: These quantities can be safely used for estimating, ordering materials and, after the work is done, as a check to prove that the required quantity of cement has been used. Actual quantity of materials used in the concrete should not vary more than ten per cent above or below the quantities given in the table.

This table can readily be used for any concrete structures which can be measured in area and which are of uniform thickness over any considerable area such as walls, floors and walks.

The following examples illustrate the use of the table:

EXAMPLE 1. Required the quantity of materials for a 12-inch thick basement wall, 6 feet 5 inches high above footing, for a house 25 feet by 40 feet outside dimensions. The footing 1 foot 6 inches wide and 6 inches thick. Concrete proportioned 1 : 3 : 5.

WALL:

Length of wall $25+25+39+39=128$ ft.
Height of wall 6 ft. 5 in. $=6\frac{5}{12}=6.417$ ft.
Area of wall $=128\times6.417=821.4$ sq. ft.
Thickness of wall $=12$ in.

Quantities of materials for wall concrete:

Factor for multiplying units in

$$\text{table } =\frac{821.4}{100}\times\frac{12}{10}=8.214\times1.2=9.8568;$$

Take 9.86

Sacks of cement $=14.2\times9.86=140.0$
Cu. yd. of sand $=1.58\times9.86=15.6$
Cu. yd. of gravel or crushed stone $=2.64\times9.86=26.0$

FOOTING:

Length of footing $=25.5+25.5+37.5+37.5=126$ ft.
Width of footing $=1$ ft. 6 in. $=1\frac{6}{12}=1.5$ ft.
Area of footing $=126\times1.5=189$ ft.
Thickness of footing $=6$ in.

Quantities of materials for footing:

Factor for multiplying units in the

$$\text{table } =\frac{189}{100}\times\frac{6}{10}=1.89\times.6=1.134=1.13$$

Sacks of cement $=14.2\times1.13=16.0$
Cu. yd. of sand $=1.58\times1.13=1.8$
Cu. yd. of gravel or stone $=2.64\times1.13=3.0$

Total quantities of materials:

Sacks of cement $=140+16=156.0$
Cu. yd. of sand $=15.6+1.8=17.4$ or 17.5
Cu. yd. of gravel $=26.0+3=29.0$

EXAMPLE 2. Required the quantities for a concrete floor for a basement. Interior dimensions of the basement 23 feet by 38 feet. Floor 5 inches thick over all, with 4-inch base of concrete proportioned 1 : 2½ : 5, and 1-inch wearing course composed of cement mortar proportioned 1 : 2.

Area of floor $=23\times38=874$ sq. ft.
Factor for multiplying quantities in table for

$$\text{base } =\frac{874}{100}\times\frac{4}{10}=8.74\times.4=3.5$$

Quantities of materials for base concrete:

Sacks of cement = 15.4 × 3.5 = 54.0
Cu. yd. of sand = 1.43 × 3.5 = 5.0
Cu. yd. of gravel or stone = 2.86 × 3.5 = 10.0

Factor for multiplying quantities in table for

$$\text{wearing surface} = \frac{874}{100} \times \frac{1}{10} = 8.74 \times .1 = .9$$

Quantities of materials for wearing surface mortar:

Sacks of cement = 39.4 × .9 = 35.5
Cu. yd. of sand = 2.92 × .9 = 2.6 cu. yd.

Total quantities of materials for floor:

Sacks of cement = 54.0 + 35.4 = 89.5
Cu. yd. of sand = 5.0 + 2.6 = 7.6 or 7.5
Cu. yd. of gravel or stone = 10.0

SURFACE AREA (IN SQUARE FEET) OF CONCRETE SLABS OR WALLS OF VARIOUS THICKNESSES AND PROPORTIONS, THAT CAN BE MADE WITH ONE SACK OF CEMENT

Thickness of Slab or Wall in inches	CONCRETE MIXTURE				
	1 : 2 : 3	1 : 2 : 4	1 : 2½ : 4	1 : 2½ : 5	1 : 3 : 5
3	15.52	17.88	19.42	21.77	23.2
3½	13.31	15.33	16.65	18.67	19.9
4	11.64	13.41	14.56	16.33	17.4
4½	10.36	11.93	12.96	14.53	15.5
5	9.31	10.73	11.65	13.06	13.9
5½	8.46	9.74	10.58	11.86	12.6
6	7.76	8.94	9.71	10.88	11.6
6½	7.18	8.27	8.98	10.07	10.7
7	6.65	7.66	8.33	9.33	9.9
8	5.82	6.70	7.28	8.16	8.7
10	4.66	5.36	5.83	6.53	6.9
12	3.88	4.47	4.85	5.44	5.8
14	3.32	3.83	4.16	4.66	4.7
16	2.91	3.35	3.64	4.08	4.3